# ELECTROSURGICAL DEVICE HAVING A TISSUE REDUCTION SENSOR

## TECHNICAL FIELD

The present invention relates generally to electrosurgical devices for use in surgical procedures and, more particularly, to an electrosurgical device having a sensor for detecting a change in tissue dimension.

## BACKGROUND

Electrosurgical devices use electrical energy, most commonly radiofrequency ("RF") energy, to cut tissue and/or cauterize blood vessels. During use, a voltage gradient is created at the tip of the device, thereby, inducing current flow and related thermal energy generation in the tissue. With appropriate levels of electrical energy, the thermal energy generated is sufficient to cut or shrink the tissue being treated, or cauterize blood vessels.

Existing electrosurgical devices can cause the temperature of the tissue being treated (e.g., the tissue treatment zone) to rise significantly higher than 100 degrees C, resulting in tissue desiccation, tissue sticking to the electrodes, tissue perforation, char formation and/or smoke generation. Peak tissue temperatures as a result of RF treatment can be as high as 350 degrees C, and such high temperatures may be transmitted to adjacent tissue via thermal diffusion. Undesirable results of such transmission to adjacent tissue include unintended thermal damage to the tissue. To reduce these undesirable results, electrosurgical devices have been developed that simultaneously introduce a fluid (e.g., an electrolytic solution with RF applications) to the tissue treatment zone, thereby, distributing the thermal energy at the tissue treatment zone, and providing cooling as well.

In many applications, it is often desirable to allow the surgeon or operator of the electrosurgical device to control the dimensional changes of the tissue being treated. Typically, this is accomplished by monitoring the temperature

at or near the tissue treatment zone. With some electrosurgical devices, the surgeon or operator can manually control the thermal energy being introduced to the tissue treatment zone. Alternatively, other electrosurgical devices can be configured to operate with a feedback control system to automatically control the thermal energy introduced to the tissue being treated. In either case, shortcomings with existing electrosurgical devices limit their effectiveness in controlling the dimensional changes of the tissue being treated.

In particular, existing electrosurgical devices monitor the temperature at or near the tissue treatment zone using a temperature sensor, such as, a thermocouple, thermistor, phosphor-coated optical fibers, or some other temperature sensor. Various factors often influence the temperature read by the temperature sensor including the temperature of the tissue being treated as well as any fluid being simultaneously infused at the tissue treatment zone. Furthermore, the temperature being read by the temperature sensor varies as the surgeon or operator moves the electrosurgical device into or out of the tissue treatment zone. As a result of these and other factors, it is often difficult to precisely achieve the desired dimensional change (e.g., the amount of shrinkage) of the tissue being treated.

Improvements in electrosurgical devices used in surgical procedures are, therefore, sought.

## SUMMARY

In general terms, the present disclosure relates to an electrosurgical device for use in surgical procedures. More particularly, the present disclosure relates to an electrosurgical device having a sensor for detecting a change in tissue dimension, such as, tissue expansion or contraction. In one aspect, the electrosurgical device comprises a main body having a proximal end and a distal end. A heat delivery modality is situated and arranged at the distal end of the main body. A sensor arrangement is also situated and arranged at the distal end of the main body. The heat delivery modality provides thermal energy to a tissue being treated while the sensor arrangement is configured to engage and detect shrinkage of the tissue being treated. In one particular aspect, the heat delivery modality can be

configured to provide a continuous flow of electrically conductive fluid to the tissue being treated while thermal energy is introduced.

Further in this aspect, the sensor arrangement can comprise at least one contact sensor situated and arranged at the distal end of the main body. In this aspect, the at least one contact sensor is constructed and arranged to engage and detect the shrinkage of the tissue being treated. Alternatively, the sensor arrangement can comprise first and second clamping members that are situated astride the main body. In this aspect, the first clamping member can include a first end pivotably connected at the main body and a second end opposite the first end. Similarly, the second clamping member can include a first end pivotably connected at the main body and a second end opposite the first end. Each of the second ends of the first and second clamping members can be constructed and arranged to engage and detect shrinkage of the tissue being treated such that the first and second clamping members rotate inwardly with respect to one another.

Still further in this aspect, the first clamping member can include a first mechanical stop for limiting the rotation of the first clamping member. Similarly, the second clamping member can include a second mechanical stop for limiting the rotation of the second clamping member. Accordingly, the first and second mechanical stops can be configured to limit the rotation of the first and second clamping members when the tissue being treated achieves a pre-determined shrinkage level.

Still further in this aspect, the first clamping member can include a first jaw and a second jaw at the second end of the first clamping member. The first and second jaws of the first clamping member can be selectively adjustable to grasp the tissue being treated. Likewise, the second clamping member can include a first jaw and a second jaw at the second end of the second clamping member. The first and second jaws of the second clamping member can be selectively adjustable to grasp the tissue being treated. Furthermore, each of the first and second jaws of the first clamping member can include a textured inner surface for resistively contacting the tissue being treated. Each of the first and second jaws of the second clamping member can also include a textured inner surface for resistively contacting the tissue

being treated. Additionally, each of the first and second jaws of the first clamping member can include a solution delivery channel for delivery of a conductive solution to the tissue being treated. Similarly, each of the first and second jaws of the second clamping member can include a solution delivery channel for delivery of a conductive solution to the tissue being treated.

The heat delivery modality can include a first electrode arrangement operable with the first clamping member. The first electrode arrangement can be coupled to a source of radio frequency energy. Similarly, the heat delivery modality can include a second electrode arrangement operable with the second clamping member. The second electrode arrangement can be coupled to the source of radio frequency energy. Moreover, the first electrode arrangement can include at least one wet electrode that is coupled to the source of radio frequency energy while the second electrode arrangement can include at least one wet electrode that is coupled to the source of radio frequency energy.

Further in this aspect, the electrosurgical device can include a forceps extending from the distal end of the main body between the first and second clamping members. The forceps can include a first arm and a second arm that is selectively adjustable to slidably receive the tissue being treated. In this aspect, the heat delivery modality can include a first electrode disposed at the first arm of the forceps and a second electrode disposed at the second arm of the forceps. Furthermore, both the first and second electrodes can be wet electrodes. Still further, the first arm of the forceps can include a first solution delivery channel for delivery of a conductive solution to the tissue being treated. Similarly, the second arm of the forceps can include a second solution delivery channel for delivery of a conductive solution to the tissue being treated.

The sensor arrangement can be configured to provide input to the heat delivery modality such that the thermal energy being provided by the heat delivery modality is varied according to the shrinkage of the tissue being treated. Alternatively, the thermal energy provided by the heat delivery modality can be minimized when the tissue being treated achieves a pre-determined shrinkage level. Furthermore, the sensor arrangement can be operably connected to a displacement measurement device for

measuring the change in shrinkage of the tissue being treated, such as, a linear potentiometer, an optical sensor, a spring/force sensor, or other measurement device.

In yet another aspect, the disclosure relates to an electrosurgical device comprising a main body having a proximal end and a distal end, a heat delivery modality situated and arranged at the distal end of the main body, and a sensor arrangement situated and arranged at the distal end of the main body. In this aspect, the heat delivery modality is capable of providing thermal energy to a tissue being treated as well as a continuous flow of electrically conductive fluid to the tissue being treated while thermal energy is introduced. The sensor arrangement is configured to engage and detect shrinkage of the tissue being treated and can comprise first and second clamping members that are situated astride the main body. In this aspect, the first clamping member can include a first end pivotably connected at the main body and a second end opposite the first end. Similarly, the second clamping member can include a first end pivotably connected at the main body and a second end opposite the first end. Each of the second ends of the first and second clamping members are preferably constructed and arranged to engage and detect shrinkage of the tissue being treated such that the first and second clamping members rotate inwardly with respect to one another.

Still further in this aspect, the first clamping member can include a first jaw and a second jaw at the second end of the first clamping member. The first and second jaws of the first clamping member can be selectively adjustable to grasp the tissue being treated. Likewise, the second clamping member can include a first jaw and a second jaw at the second end of the second clamping member. The first and second jaws of the second clamping member can be selectively adjustable to grasp the tissue being treated. Furthermore, each of the first and second jaws of the first clamping member can include a textured inner surface for resistively contacting the tissue being treated. Each of the first and second jaws of the second clamping member can also include a textured inner surface for resistively contacting the tissue being treated. Additionally, each of the first and second jaws of the first clamping member can include a solution delivery channel for delivery of a conductive solution to the tissue being treated. Similarly, each of the first and second jaws of the second clamping member

can include a solution delivery channel for delivery of a conductive solution to the tissue being treated.

Still further in this aspect, the heat delivery modality can include a first electrode arrangement operable with the first clamping member and coupled to a source of radio frequency energy. Similarly, the heat delivery modality can include a second electrode arrangement operable with the second clamping member and coupled to the source of radio frequency energy. The first electrode arrangement can include at least one wet electrode that is coupled to the source of radio frequency energy. Similarly, the second electrode arrangement can include at least one wet electrode that is coupled to the source of radio frequency energy.

Further in this aspect, the electrosurgical device can include a forceps extending from the distal end of the main body between the first and second clamping members. The forceps can include a first arm and a second arm that is selectively adjustable to slidably receive the tissue being treated. In this aspect, the heat delivery modality can include a first wet electrode disposed at the first arm of the forceps and coupled to a source of radio frequency energy. Similarly, the heat delivery modality can include a second wet electrode disposed at the second arm of the forceps and coupled to a source of radio frequency energy. Still further, the first arm of the forceps can include a first solution delivery channel for delivery of a conductive solution to the tissue being treated. Similarly, the second arm of the forceps can include a second solution delivery channel for delivery of a conductive solution to the tissue being treated.

The sensor arrangement can be configured to provide input to the heat delivery modality such that the thermal energy being provided by the heat delivery modality is varied according to the shrinkage of the tissue being treated. Alternatively, the thermal energy provided by the heat delivery modality can be minimized when the tissue being treated achieves a pre-determined shrinkage level. Furthermore, the sensor arrangement can be operably connected to a displacement measurement device for measuring the change in shrinkage of the tissue being treated, such as, a linear potentiometer, an optical sensor, a spring/force sensor, or other measurement device.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be more completely understood in consideration of the following detailed description of various embodiments of the invention in connection with the accompanying drawings, in which:

FIG. **1** is a high-level diagram illustrating one possible embodiment of an electrosurgical device having a sensor for detecting a change in tissue dimension in accordance with the present disclosure connected to a power source and an electronic controller;

FIG. **2** is an enlarged, top view illustrating the electrosurgical device of FIG. **1** having a sensor for detecting a change in tissue dimension;

FIG. **3** is an enlarged, side section view illustrating the electrosurgical device of FIG. **2** having a sensor for detecting a change in tissue dimension;

FIG. **4** is an enlarged, a top view illustrating the electrosurgical device of FIG. **2** having a tissue positioned within the device;

FIG. **5** is an enlarged, side section view illustrating the electrosurgical device of FIG. **4**;

FIG. **6** is an enlarged, top view illustrating a second possible embodiment of the electrosurgical device of FIG. **1**;

FIG. **7** is an enlarged, side section view illustrating the electrosurgical device of FIG. **6** having a sensor for detecting a change in tissue dimension;

FIG. **8** is an enlarged, a top view illustrating the electrosurgical device of FIG. **6** having a tissue positioned within the device;

FIG. **9** is an enlarged, side section view illustrating the electrosurgical device of FIG. **8**; and

FIG. **10** illustrates an alternative configuration of the electrosurgical device of FIG. **1** for measuring change in tissue dimension in accordance with the present disclosure.

While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the

drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

## DETAILED DESCRIPTION

Various embodiments of the present invention will be described in detail with reference to the drawings, wherein like reference numerals represent like parts and assemblies throughout the several views. Reference to various embodiments does not limit the scope of the present invention, which is limited only by the scope of the claims attached hereto.

The following discussion is intended to provide a brief, general description of a suitable medical device for precisely measuring and/or controlling a change in tissue dimension during surgical applications. As will become apparent from the discussion below in connection with the accompanying drawings, the present disclosure has particularized applicability to electrosurgical devices having a tissue reduction or shrinkage sensor. However, it will be appreciated by those having skill in the art that the present disclosure is not limited to the specific embodiments discussed below. Rather, the medical device of the present disclosure may be implemented during any surgical procedure where thermal energy is being used to contract and/or expand collagen and it is desirous to precisely measure and/or control the change in dimension of the tissue being treated. By "change in dimension," it is generally meant that the electrosurgical device of the present disclosure is able to measure and/or control the shortening, lengthening, widening, thinning, or other similar dimensional variations, of the tissue being treated.

Now referring to FIG. **1**, a medical device or electrosurgical device **100** for use during surgical procedures in accordance with the principles of the present disclosure is shown. The electrosurgical device **100** generally includes a main body **102** having a proximal end **106** and a distal end **108**. The phrase "proximal end" is generally meant to refer to the portion of the electrosurgical

device **100** that is held in the operator's hand during use. Conversely, the phrase "distal end" is generally meant to refer to the portion of the electrosurgical device **100** at or near a location that contacts the patient. The main body **102** can include a handle portion **104** at or near its proximal end **106** and an end effector region **E** at or near its distal end **108**. In the illustrated embodiment, the handle portion **104** depends downwardly along the main body portion **102** away from the end effector region **E** to provide a suitable area for gripping or handling the electrosurgical device **100** during use. By "downwardly," it is generally meant that in the orientation shown in FIG. **1**, the handle portion **104** extends below the end effector region **E**.

As shown in FIG. **1**, the electrosurgical device **100** is connected to a power source **118** via a pair of conductors **120**. The power source **118** supplies energy to the electrosurgical device **100**. Furthermore, as shown in the illustrated embodiment, the electrosurgical device **100** can be configured to provide feedback to an electronic controller **116** that is configured to modulate the energy supplied by the power source **118**.

The end effector region **E** generally includes an arrangement for delivering thermal energy to the tissue (not shown) being treated. In the embodiments illustrated in the accompanying drawings, the arrangement for delivering thermal energy can comprise a heat delivery modality **110** capable heating the tissue being treated, thereby, causing the tissue to contract. However, as discussed above, one skilled in the art will readily appreciate that the arrangement for delivering thermal energy can comprise a device capable of cooling the tissue being treated, thereby, causing the tissue to expand. The heat delivery modality **110** generally can include any mechanism capable of delivering thermal energy to the tissue being treated, such as, RF energy, microwave energy, coherent (e.g., laser) and incoherent light energy, direct thermal transfer, electrical resistive heating, as well as other similar forms of energy. One skilled in the art will readily appreciate that the heat delivery modality **118** can be connected to any suitable energy source capable of introducing thermal energy to the tissue being treated, thereby, causing the tissue to contract.

In addition to the heat delivery modality **110**, the end effector region **E** also includes a sensor arrangement **112**. The sensor arrangement **112** generally can include any device capable of engaging and detecting a change in dimension, such as, shrinkage or expansion, of the tissue (not shown) being treated as thermal energy is introduced. For example, the sensor arrangement **112** can include at least one contact sensor situated and arranged at the distal end **108** of the main body **102**. While many embodiments of the sensor arrangement **112** are contemplated, the sensor arrangement illustrated in FIG. **1**, generally includes a first contact sensor **114a** and a second contact sensor **114b**, such as, clamping members, needles, or other devices, configured to grasp or embed within the tissue being treated. One or both of the contact sensors **114a, 114b** can be pivotably attached to the main body **102** of the electrosurgical device **100** such that the contact sensors **114a, 114b** move relative to the change in dimension of the tissue being treated. For example, in the illustrated embodiment, the contact sensors **114a, 114b** move relative to the shrinkage of the tissue being treated. As a result, the sensor arrangement **112** is able to detect the shrinkage of the tissue being treated, thereby, allowing the surgeon or operator to precisely shrink or contract the tissue being treated.

For example, in one embodiment, the surgeon or operator can precisely shrink or contract the tissue by manually adjusting the power source **118** when the tissue shrinks to a desired level. Alternatively, as discussed above, the electrosurgical device **100** can be configured to provide a feedback control signal to the electronic controller **116** that is configured to modulate the energy supplied by the power source **118** such that the electrosurgical device **100** can automatically shrink or contract the tissue being treated to a predetermined level. The predetermined level can be established according to preset criteria, such as, shrinkage percentage or total tissue length reduction. Specific embodiments of the heat delivery modality **110** and the sensor arrangement **112** will be discussed in greater detail below.

A first embodiment of an electrosurgical device **100** for use in accordance with the principles of the present disclosure will now be described in connection with FIGS. **2-5**. As shown in FIGS. **2** and **3**, the end effector region **E** can include a forceps **130** for receiving the target tissue (not shown) to be treated. As

shown in FIG. **3**, the forceps **130** includes a first arm **130a** and a second arm **130b**. In the illustrated embodiment, the first and second arms **130a**, **130b** are spaced apart a distance $\mathbf{D_F}$ to define a passageway therebetween. Preferably, the forceps **130** slidably receive the target tissue to be treated within the passageway defined between the first and second arms **130a**, **130b**. By "slidably receive," it is generally meant that the distance $\mathbf{D_F}$ can be selectively adjusted such that the first and second arms **130a**, **130b** of the forceps **130** maintain slidable contact with and do not restrict the movement of the target tissue to be treated when it is received within the passageway. Thus, the forceps **130** allow the tissue being treated to shrink as thermal energy is introduced to the treatment zone.

The forceps **130** define a heat delivery modality **110** for providing thermal energy to the tissue (not shown) being treated. While many embodiments of the heat delivery modality **110** are contemplated, in the illustrated embodiment, the heat delivery modality **110** defined by the forceps **130** includes an electrode arrangement **131** for providing thermal energy to the tissue being treated. In particular, as shown in FIG. **3**, the first arm **130a** of the forceps **130** can include a first electrode **132**, and the second arm **130b** can include a second electrode **134** having a polarity opposite the first electrode **132**. The electrode arrangement **131** illustrated in FIG. **3** is a bipolar configuration. However, one skilled in the art will readily appreciate that the electrosurgical device **100** of the present disclosure can be implemented using a monopolar electrode arrangement.

In one possible embodiment, the first and second electrodes **132**, **134** can be selectively energized to provide thermal energy to the tissue being treated. In a preferred embodiment, the thermal energy supplied to the tissue being treated is produced as a result of a voltage gradient created by a RF energy power source **118** (FIG. 1). However, it will be appreciated that the thermal energy supplied to the tissue being treated can be provided by any suitable energy source sufficient to allow the tissue being treated to shrink or contract. For example, as discussed above, the energy source **118** connected to the heat delivery modality **131** can be microwave energy, coherent (e.g., laser) or incoherent light energy, direct thermal transfer, electrical resistive heating, as well as other similar forms or sources of energy.

Preferably, the electrode arrangement **131** discussed above is a wet electrode arrangement and is used in conjunction with a conductive fluid (e.g., an electrolytic solution). The use of a conductive fluid in connection with the electrode arrangement **131** allows the thermal energy to be distributed equally, thereby, minimizing hot spots within the tissue being treated. In the embodiment illustrated in FIG. **3**, the first arm **130a** of the forceps **130** (FIG. **2**) is provided with a solution delivery channel **138**. Similarly, the second arm **130b** is provided with a solution delivery channel **142**. The solution delivery channels **138**, **142** provide a path for fluid communication between a fluid source (not shown) and the forceps **130**. In particular, the solution delivery channel **138** provides a path for fluid communication between a fluid source and the first arm **130a** and the solution delivery channel **142** provides a path for fluid communication between a fluid source and the second arm **130b**. Fluid can flow from the solution delivery channel **138** through small holes (not shown) in the first electrode **132** and into a region **132'** located between the first electrode **132** and the tissue (not shown). Similarly, fluid can flow from the solution delivery channel **142** through small holes (not shown) in the second electrode **134** and into a region **134'** located between the second electrode **134** and the tissue. In so doing, the electrosurgical device **100** can introduce a conductive fluid, such as, a saline solution or other similar electrolytic solution, at the electrode/tissue interface to minimize the amount of tissue damage, char formation, smoke generation or other similar damage to the tissue being treated.

In addition to the heat delivery modality **110**, the end effector region **E** also includes a sensor arrangement **112** configured to engage and detect a change in dimension of the tissue being treated. For example, in the illustrated embodiment, the sensor arrangement **112** can be used to measure the shrinkage or contraction of the tissue being treated. The sensor arrangement **112** generally includes at least one contact sensor situated and arranged at the distal end **108** of the main body **102**. Exemplary contact sensors capable of engaging and detecting shrinkage of the tissue being treated include, but are not limited to, clamping members, needles, or other devices that can grasp or embed within the tissue being treated. While many embodiments of the sensor arrangement **112** are contemplated, in the illustrated embodiment, the sensor

arrangement **112** includes a first clamp **140** and a second clamp **160** situated and arranged astride the forceps **130**. By "astride," it is generally meant that the forceps **130** is situated and arranged between the first and second clamps **140, 160**.

As shown in FIG. **3**, the first clamp **140** can comprise first and second symmetrical jaw members **140a, 140b**. Each of the jaw members **140a, 140b** include a lower arm member **142** (FIG. **2**) extending away from the main body portion **102** of the device **100** and an upper flange member **144** (FIG. **2**). In this embodiment, an elbow or shoulder **146** (FIG. **2**) is defined by the intersection of the lower arm member **142** and the upper flange **144**. The first and second symmetrical jaw members **140a, 140b** also include a proximal end portion **148** (FIG. **2**) and a distal end portion **150** (FIG. **2**). The phrase "proximal end portion" is generally meant to refer to the portion of each of the first and second jaw members **140a, 140b** at or near their point of attachment to the main body **102**. Likewise, the phrase "distal end portion" is generally meant to refer to the portion of each of the first and second jaw members **140a, 140b** at or near a location furthest from their point of attachment to the main body **102**.

Similarly, the second clamp **160** comprises first and second symmetrical jaw members **160a, 160b**. Each of the jaw members **160a, 160b** include a lower arm member **162** (FIG. **2**) extending away from the main body portion **102** of the device **100** and an upper flange member **164** (FIG. **2**). In this embodiment, an elbow or shoulder **166** (FIG. **2**) is defined by the intersection of the lower arm member **162** and the upper flange **164**. Each of the jaw members **160a, 160b** comprising the second clamp **160** also include a proximal end portion **168** (FIG. **2**) and a distal end portion **170** (FIG. **2**). As with the first clamp **140** discussed above, the phrase "proximal end portion" is generally meant to refer to the portion of each of the first and second jaw members **160a, 160b** at or near their point of attachment to the main body **102**. Similarly, the phrase "distal end portion" is generally meant to refer to the portion of each of the jaw members **160a, 160b** at or near a location furthest from their point of attachment to the main body **102**.

In the illustrated embodiment, the first and second symmetrical jaw members **140a, 140b** comprising the first clamp **140** are spaced apart a distance $\mathbf{D_c}$ to define a passageway for receiving the tissue being treated. In one possible embodiment,

the distance $\mathbf{D_c}$ can be selectively adjusted, thereby, increasing or decreasing the compressive forces being applied to the tissue being treated. Moreover, the first and second jaw members **140a**, **140b** can include inner surfaces **141a**, **141b**, respectively, that resistively contact the tissue being treated. By "resistively contact," it is generally meant that the inner surfaces **141a**, **141b** are textured such that the first clamp **140** can maintain a grasp on the tissue being treated. For example, the inner surfaces **141a**, **141b** can include serrations, grooves, or any other surface roughness that increase the friction between the first clamp **140** and the tissue being treated.

Similarly, the first and second symmetrical jaw members **160a**, **160b** comprising the second clamp **160** are spaced apart a distance $\mathbf{D_c}$ to define a passageway for receiving the tissue being treated. As discussed above in connection with the first clamp **140**, in one possible embodiment, the distance $\mathbf{D_c}$ can be selectively adjusted to increase or decrease the compressive forces being applied to the tissue being treated. Moreover, the first and second jaw members **160a**, **160b** comprising the second clamp **160** can include inner surfaces **161a**, **161b** that resistively contact the tissue being treated. By "resistively contact," it is generally meant that the inner surfaces **161a**, **161b** are textured such that the second clamp **160** maintains a grasp on the tissue being treated. For example, the inner surfaces **161a**, **161b** can include serrations, grooves, or any other similar surface roughness that increase the friction between the second clamp **160** and the tissue being treated.

Now in reference to FIGS. **4** and **5**, a tissue **180**, such as, a tendon or ligament is shown positioned between the forceps **130** and the first and second clamps **140**, **160** of the electrosurgical device **100**. More particularly, the tissue **180** is shown positioned between the first and second arms **130a**, **130b** of the forceps **130**. Similarly, the tissue **180** is shown positioned between the first and second jaws **140a**, **140b** of the first clamp **140** and the first and second jaws **160a**, **160b** of the second clamp **160**. As discussed above, the operator of the electrosurgical device **100** can selectively energize the heat delivery modality **110** to provide thermal energy to the tissue treatment zone. In the illustrated embodiment, the operator of the electrosurgical device **100** can selectively energize the electrode arrangement **131** (e.g., the first and second electrodes **132**, **134**) to induce an electric current through the tissue **180** being treated or, more

particularly, the treatment zone. As used herein, the phrase "treatment zone" generally refers to the portion or area of the tissue **180** located adjacent to and/or substantially between the first and second arms **130a, 130b** of the forceps **130**. In the illustrated embodiment, the thermal energy passes through the treatment zone as shown by the dotted lines in FIG. **5**.

The thermal energy causes the tissue **180** within the treatment zone to contract or shrink. As discussed above, it is typically desirable to allow the surgeon or operator of the electrosurgical device **100** to control the shrinkage of the tissue **180**. Existing electrosurgical devices monitor the temperature at or near the treatment zone to allow the surgeon to control the thermal energy introduced to the tissue treatment zone. The electrosurgical device **100** of the present disclosure, however, allows the operator to precisely control the thermal energy being introduced to the tissue treatment zone by monitoring the shrinkage of the tissue **180** being treated. Accordingly, the shrinkage of the tissue **180** being treated can be more precisely controlled.

To accomplish this, the sensor arrangement **112** is configured to engage or contact the tissue **180**, thereby, sensing or detecting the shrinkage or contraction of the tissue **180** as thermal energy is introduced to the tissue treatment zone. For example, in the illustrated embodiment, the first and second clamping members **140**, **160** are shown in engagement with the tissue **180** outside of the tissue treatment zone. In this embodiment, the first clamp **140** is preferably pivotably connected to the main body **102** at or near a pivot position **152**. As a result, the first clamp **140** is able to rotate about the pivot position **152** such that the upper flange **144** (FIG. **2**) moves inwardly towards the forceps **130**. By "inwardly," it is generally meant that the first clamp **140** moves leftward and towards the forceps **130** such that the lateral distance $\mathbf{D_L}$ (FIG. **2**) between the first clamp **140** and the forceps **130** is reduced. Similarly, the second clamp **160** is preferably pivotably connected to the main body **102** at or near a pivot position **172**. As a result, the second clamp **160** is able to rotate about the pivot position **172** such that the upper flange **164** moves inwardly towards the forceps **130**. By "inwardly," it is generally meant that in the orientation shown in FIG. **2**, the second clamp **160** moves rightward and towards the forceps **130** such that the lateral distance $\mathbf{D_L}$ (FIG. **2**) between the second clamp **160** and the forceps **130** is reduced. While the

first and second clamps **140**, **160** are pivotably connected to the main body **102**, one skilled in the art will readily appreciate that the first and second clamps **140**, **160** can be slidably connected to the main body **102** so that they are able to slide back and forth relative to the expansion and/or contraction of the tissue **180** being treated.

As a result of this configuration, the electrosurgical device **100** is able to detect a change in dimension of the tissue **180** being treated as thermal energy is introduced to the treatment zone. In particular, in the illustrated embodiment, the electrosurgical device **100** is able to detect the shrinkage or contraction of the tissue **180** being treated as thermal energy is introduced to the treatment zone. Furthermore, the electrosurgical device **100** is able to detect the recovery or expansion of the tissue **180** being treated as the thermal energy (e.g., heat) is removed from the treatment zone. In a preferred embodiment, the electrosurgical device **100** also can include a displacement measurement device **174** for measuring the change in dimension of the tissue **180**, for example, the shrinkage or contraction of the tissue **180** being treated. In particular, in the illustrated embodiment, the first and second clamps **140**, **160** are coupled to a displacement measurement device **174** that measures the angular or rotational displacement of the first and second clamps **140**, **160** as thermal energy is introduced to the treatment zone. For example, the first and second clamps **140**, **160** can be coupled to a linear potentiometer, optical sensor, spring/force sensor, or other similar displacement measurement device for measuring the angular or rotation displacement of the first and second clamps **140**, **160**.

The amount change in the dimension of the tissue **180** being treated can be determined by calculating the displacement of each of the contact sensors used to engage the tissue **180**. In the illustrated embodiment, the amount of shrinkage in the tissue **180** is determined by calculating the angular displacement of the first and second clamps **140**, **160**. Once the desired shrinkage of the tissue **180** has been achieved, the displacement measurement device **174** can provide a control signal to the electronic control unit **116** (FIG. **1**) to reduce or minimize the amount of thermal energy being supplied to treatment zone by regulating the power source **118** (FIG. **1**). Alternatively, the first and second clamps **140**, **160** can include a mechanical stop (not shown) to prevent shrinkage of the tissue beyond a pre-determined amount or percentage.

A second possible embodiment of a medical device for use in accordance with the principles of the present disclosure will now be described in connection with FIGS. **6-9**. As shown in FIG. **6**, the electrosurgical device **200** generally includes a main body **202** having a proximal end **206** and a distal end **208**. The phrase "proximal end" is generally meant to refer to the portion of the electrosurgical device **200** that is held in the operator's hand during use. Conversely, the phrase "distal end" is generally meant to refer to the portion of the electrosurgical device **200** at or near a location that contacts the patient. The main body **202** can include a handle portion **204** at or near its proximal end **206** and an end effector region **E'** at or near its distal end **208**. In the illustrated embodiment, the handle portion **204** depends downwardly along the main body portion **202** away from the end effector region **E'** to provide a suitable area for gripping or handling the electrosurgical device **200** during use. By "downwardly," it is generally meant that in the orientation shown in FIG. **5**, the handle portion **204** extends below the end effector region **E'**.

In this embodiment, the end effector region **E'** includes a sensor arrangement **212** that is configured to engage and detect a change in dimension of the tissue being treated. The sensor arrangement **212** generally includes at least one contact sensor situated and arranged at the distal end **208** of the main body **202**. Exemplary contact sensors capable of engaging and detecting a change in dimension of the tissue being treated include, but are not limited to, clamping members, needles, or other devices that can grasp or embed within the tissue being treated. While many embodiments of the sensor arrangement **212** are contemplated, in the illustrated embodiment, the sensor arrangement **212** includes a first clamp **240** and a second clamp **260** situated and arranged astride the main body **202**.

As shown in FIG. **7**, the first clamp **240** can comprise first and second symmetrical jaw members **240a**, **240b**. Each of the jaw members **240a**, **240b** include a lower arm member **242** (FIG. **6**) extending away from the main body portion **202** of the device **200** and an upper flange member **244** (FIG. **6**). In this embodiment, an elbow or shoulder **246** (FIG. **6**) is defined by the intersection of the lower arm member **242** and the upper flange **244**. The first and second symmetrical jaw members **240a**, **240b** also include a proximal end portion **248** (FIG. **6**) and a distal end portion **250** (FIG. **6**). The

phrase "proximal end portion" is generally meant to refer to the portion of each of the first and second jaw members **240a, 240b** at or near their point of attachment to the main body **202**. Likewise, the phrase "distal end portion" is generally meant to refer to the portion of each of the first and second jaw members **240a, 240b** at or near a location furthest from their point of attachment to the main body **202**.

Similarly, the second clamp **260** can comprise first and second symmetrical jaw members **260a, 260b**. Each of the jaw members **260a, 260b** include a lower arm member **262** (FIG. **6**) extending away from the main body portion **202** of the device **200** and an upper flange member **264** (FIG. **6**). In this embodiment, an elbow or shoulder **266** (FIG. **6**) is defined by the intersection of the lower arm member **262** and the upper flange **264**. Each of the jaw members **260a, 260b** comprising the second clamp **260** also include a proximal end portion **268** (FIG. **6**) and a distal end portion **270** (FIG. **6**). As with the first clamp **240** discussed above, the phrase "proximal end portion" is generally meant to refer to the portion of the second clamp **260** at or near it point of attachment to the main body **202**. Similarly, the phrase "distal end portion" is generally meant to refer to the portion of each of the jaw members **260a, 260b** at or near a location furthest from its point of attachment to the main body **202**.

In the illustrated embodiment, the first and second symmetrical jaw members **240a, 240b** comprising the first clamp **240** are spaced apart a distance $\mathbf{D_c}$**'** to define a passageway for receiving the tissue being treated. In one possible embodiment, the distance $\mathbf{D_c}$**'** can be selectively adjusted, thereby, increasing or decreasing the compressive forces being applied to the tissue being treated. Moreover, the first and second jaw members **240a, 240b** can include inner surfaces **241a, 241b** that resistively contact the tissue being treated. By "resistively contact," it is generally meant that the inner surfaces **241a, 241b** are textured such that the first clamp **240** maintains a grasp on the tissue being treated. For example, the inner surfaces **241a, 241b** can include serrations, grooves, or any other similar surface roughness that increase the friction between the first clamp **240** and the tissue being treated.

Similarly, the first and second symmetrical jaw members **260a, 260b** comprising the second clamp **260** are spaced apart a distance $\mathbf{D_c}$**'** to define a passageway for receiving the tissue being treated. As discussed above in connection with the first

clamp **240**, in one possible embodiment, the distance **$D_c$'** can be selectively adjusted to increase or decrease the compressive forces being applied to the tissue being treated. Moreover, the first and second jaw members **260a, 260b** comprising the second clamp **260** can include inner surfaces **261a, 261b** that resistively contact the tissue being treated. By "resistively contact," it is generally meant that the inner surfaces **261a, 261b** are textured such that the second clamp **260** maintains a grasp on the tissue being treated. For example, the inner surfaces **261a, 261b** can include serrations, grooves, or any other surface roughness that increase the friction between the second clamp **260** and the tissue being treated.

As with the first embodiment discussed above, the end effector region **E'** includes a heat delivery modality **210** for providing thermal energy to the tissue being treated. While many embodiments of the heat delivery modality **210** are contemplated, in the illustrated embodiment, the heat delivery modality **210** includes an electrode arrangement for providing thermal energy to the tissue being treated. In particular, as shown in FIG. **7**, the heat delivery modality **210** can include a first electrode arrangement **231a** operable with the first clamp **240** and a second electrode arrangement **231b** operable with the second clamp **260**. The first electrode arrangement **231a** includes a first electrode **232** at the first jaw member **240a** of the first clamp **240** and a second electrode **233** at the second jaw member **240b**. Similarly, the second electrode arrangement **231b** includes a first electrode **234** at the first jaw member **260a** of the second clamp **260** and a second electrode **235** at the second jaw member **260b**. In one possible embodiment, the first and second electrodes **232, 233** at the first clamp **240** and the first and second electrodes **234, 235** at the second clamp **260** can be selectively energized to provide electrical energy to the tissue being treated. In a preferred embodiment, the thermal energy provided to the tissue being treated is RF energy.

In the embodiment illustrated in FIG. **7**, the first and second jaw members **240a, 240b** of the first clamp **240** is preferably provided with a solution delivery channel. In particular, a first solution delivery channel **236** is provided within the first jaw member **240a** and a second solution delivery channel **237** is provided within the second jaw member **240b**. The solution delivery channels **236, 237** provide a path for fluid communication between a fluid source (not shown) and the first clamp

**240**. Specifically, the solution delivery channel **236** provides a path for fluid communication between a fluid source and the first jaw member **240a** and the solution delivery channel **237** provides a path for fluid communication between a fluid source and the second jaw member **240b**. Fluid can flow from the solution delivery channel **236** through small holes (not shown) in the first electrode **232** (at the first clamp **240**) and into a region **232'** located between the first electrode **232** and the tissue (not shown). Similarly, fluid can flow from the solution delivery channel **237** through small holes (not shown) in the second electrode **233** (at the first clamp **240**) and into a region **233'** located between the second electrode **233** and the tissue.

Similarly, the first and second jaw members **260a, 260b** of the second clamp **260** is preferably provided with a solution delivery channel. In particular, a first solution delivery channel **238** is provided within the first jaw member **260a** and a second solution delivery channel **239** is provided within the second jaw member **260b**. The solution delivery channels **238, 239** provide a path for fluid communication between a fluid source (not shown) and the second clamp **260**. Specifically, the first solution delivery channel **238** provides a path for fluid communication between a fluid source and the first jaw member **260a** and the second solution delivery channel **239** provides a path for fluid communication between a fluid source and the second jaw member **260b**. Fluid can flow from the solution delivery channel **238** through small holes (not shown) in the first electrode **234** (at the second clamp **260**) and into a region **234'** located between the first electrode **234** and the tissue (not shown). Similarly, fluid can flow from the solution delivery channel **239** through small holes (not shown) in the second electrode **235** (at the second clamp **260**) and into a region **235'** located between the second electrode **233** and the tissue. In providing the solution delivery channels **236, 237, 238, 239**, the electrosurgical device **200** of the present disclosure is able to introduce a conductive fluid, such as, a saline solution or other similar electrolytic solution, at the electrode/tissue interface to minimize the amount of tissue damage, char formation, smoke generation or other similar damage to the tissue being treated.

Now in reference to FIGS. **8** and **9**, a tissue **280** such as, a tendon or ligament is shown positioned between the first and second clamps **240, 260** of the electrosurgical device **200**. More particularly, the tissue **280** is shown positioned

between the first and second jaws **240a, 240b** of the first clamp **240** and the first and second jaws **260a, 260b** of the second clamp **260**. As discussed above, the operator of the electrosurgical device **200** can selectively energize the first and second electrodes **232, 233** situated at the first clamp **240** and the first and second electrode **234, 235** situated at the second clamp **260** to provide thermal energy to the tissue **280** being treated or, more particularly, the treatment zone. As used herein, the phrase "treatment zone" generally refers to the portion or area of the tissue **280** located adjacent to and/or substantially between the first and second clamps **240, 260**. In the illustrated embodiment, thermal energy passes through the treatment zone as shown by the dashed lines in FIG. **9**.

The thermal energy causes the tissue **280** within the treatment zone to contract or shrink. As with the first embodiment disclosed above, the electrosurgical device **200** allows the operator to precisely control the thermal energy being introduced to the tissue treatment zone by monitoring the shrinkage of the tissue **280** being treated. Accordingly, the shrinkage of the tissue **280** can be more precisely controlled.

To accomplish this, the sensor arrangement **212** is configured to engage or contact the tissue **280**, thereby, sensing or detecting the shrinkage or contraction of the tissue **280** as thermal energy is introduced to the treatment zone. For example, in the illustrated embodiment, the first and second clamping members **240, 260** are shown in engagement with the tissue **280**. In this embodiment, the first clamp **240** is preferably pivotably connected to the main body **202** at or near a pivot position **252**. As a result, the first clamp **240** is able to rotate about the pivot **252** such that the upper flange **244** (FIG. **6**) moves inwardly towards a reference axis **A-A** extending upwards from the main body 202 as shown in FIG. **6**. By "inwardly," it is generally meant that the first clamp **240** moves leftward and towards the reference axis **A-A** such that the lateral distance $\mathbf{D'_L}$ between the first clamp **240** and the reference axis **A-A** is reduced. Similarly, the second clamp **260** is preferably pivotably connected to the main body **202** at or near a pivot position **272**. As a result, the second clamp **260** is able to rotate about the pivot **272** such that the upper flange **264** moves inwardly towards the reference axis **A-A**. By "inwardly," it is generally meant that in the orientation shown in FIG. **5**, the

second clamp **260** moves rightward and towards the reference axis **A-A** such that the lateral distance $\mathbf{D'_L}$ between the second clamp **260** and the reference axis is reduced.

As a result of this configuration, the electrosurgical device **200** is able to detect a change in dimension of the tissue **280** being treated as thermal energy is introduced to the treatment zone. In particular, in the illustrated embodiment, the electrosurgical device **200** is able to detect the shrinkage or contraction of the tissue **280** being treated as thermal energy is introduced to the treatment zone. Furthermore, the electrosurgical device **200** is able to detect the recovery or expansion of the tissue **280** being treated as the thermal energy (e.g., heat) is removed from the treatment zone. In a preferred embodiment, the electrosurgical device 2**00** also can include a displacement measurement device **274** for measuring the shrinkage or contraction of the tissue **280** being treated. In particular, the first and second clamps **240, 260** are coupled to a displacement measurement device **274** that measures the angular or rotational displacement of the first and second clamps **240, 260** as thermal energy is introduced to the treatment zone. For example, the first and second clamps **240, 260** can be coupled to a linear potentiometer, optical sensor, spring/force sensor, or other similar sensing device for measuring the angular or rotation displacement of the first and second clamps **240, 260.**

The amount of shrinkage or contraction in the tissue **280** can be determined by calculating the displacement of each contact sensors used to engage and detect shrinkage of the tissue **280**. In the illustrated embodiment, the amount of shrinkage in the tissue **280** is determined by calculating the angular displacement of the first and second clamps **240, 260**. Once the desired shrinkage of the tissue **280** has been achieved, the displacement measurement device **274** can provide a control signal to the electronic control unit **116** (FIG. **1**) to reduce or minimize the amount of thermal energy being supplied to treatment zone by regulating the power source **118** (FIG. **1**). Alternatively, the first and second clamps **240, 260** can include a mechanical stop (not shown) to prevent shrinkage of the tissue beyond a pre-determined amount or percentage.

As an alternative to using a sensor arrangement to detect a change in dimension in the tissue being treated, a visual indicator can be used to allow the

operator or surgeon to visually detect the shrinkage or contraction of the tissue being treated. For example, as shown in FIG. **10**, a visual indicator **282** can be used to measure the shrinkage of the tissue **280**. In one possible embodiment, the visual indicator **282** can be applied to the surface of the tissue **280**. Preferably, the visual indicator **282** is applied to the surface of the tissue **280** between the first and second clamps **240**, **260** using a non-toxic ink or other substance capable of being applied to a tissue. In so doing, the operator can visually inspect the indicator **282** as the thermal energy is being introduced into the treatment zone. In particular, as the tissue **280** shrinks due to the thermal energy being supplied to the treatment zone, the visual indicator **282** changes shape. In the illustrated embodiment, the visual indicator **282** prior to the introduction of thermal energy is an elliptical pattern **284**. After the tissue **280** shrinks due to the introduction of the thermal energy, the visual indicator **282** shrinks to a circular pattern **284'**. Once the visual indicator shrinks to the appropriate pattern, the operator or surgeon can reduce the amount of thermal energy being supplied by the heat delivery modality **210** by regulating the power source **118** (FIG. **1**).

The various embodiments described above are provided by way of illustration only and should not be construed to limit the invention. Those skilled in the art will readily recognize the various modifications and changes which may be made to the present invention without strictly following the exemplary embodiments illustrated and described herein, and without departing from the true spirit and scope of the present invention, which is set forth in the following claims.